GED-C 80/95-1

REPORT OF
DEPARTMENT OF DEFENSE
ADVISORY GROUP ON ELECTRON DEVICES
WORKING GROUP C (ELECTRO-OPTICS)

SPECIAL TECHNOLOGY AREA REVIEW
ON
ALTERNATE DETECTOR MATERIALS
TO InSb AND HgCdTe

CLEARED
FOR OPEN PUBLICATION
This is a SAF/PAS document

01 FEB 0 4 2002 11

DIRECTORATE FOR FREEDOM OF INFORMATION
AND SECURITY REVIEW
DEPARTMENT OF DEFENSE

CLEARED
FOR OPEN PUBLICATION

FEB 0 4 2002 11

DIRECTORATE FOR FREEDOM OF INFORMATION
AND SECURITY REVIEW
DEPARTMENT OF DEFENSE

NOVEMBER 8 1995

OFFICE OF THE UNDER SECRETARY OF DEFENSE
ACQUISITION AND TECHNOLOGY
WASHINGTON, D.C. 20301-3140

CONTRIBUTORS

Dr. Susan Turnbach
Executive Director, Advisory Group on Electron Devices
ODDR&E/AT, The Pentagon
Washington, DC

Dr. Ronald Paulson
Chairman, Working Group C (Electro-Optics)
Advisory Group on Electron Devices
Washington, DC

STAR Chairman .... Dr. Arthur Lockwood

John Bruno
Army Research Laboratory

Wayne Chang
Army Research Laboratory

Thomas Faska
Martin Marietta

Charles Hanson
Texas Instruments

Paul Kelley *
Tufts University

Richard Lane
Air Force Wright Laboratory

Frederick Leonberger
UT Photonics

Thomas Lewis
Advanced Photonix

John Malamas *
Army Research Laboratory

Richard Mannello
Loral

John McMahon *
Naval Research Laboratory

M. Robert Miller *
Army Research Laboratory

William Mitchell
Air Force Wright Laboratory

John Pollard
Army CECOM NVESD

Richard Payne
Air Force Rome Laboratory

William Radford
Hughes Santa Barbara Res Ctr

Freeman Shepherd
Air Force Rome Laboratory

Arden Sher
SRI International

Anjali Singh
Air Force Phillips Laboratory

Donald J. Smith *
Air Force Wright Laboratory

William Tennant
Rockwell International

James Waterman
Naval Research Laboratory

Raymond Whitney
Lockheed

Andrew Wood
Honeywell

Jane Zucker *
AT&T Bell Laboratories

* Advisory Group on Electron Devices (AGED)

Table of Contents

Figures and Tables

REPORT ON THE SPECIAL TECHNOLOGY AREA REVIEW (STAR) ON DETECTOR MATERIAL ALTERNATIVES TO InSb AND HgCdTe

EXECUTIVE SUMMARY - CONCLUSIONS AND RECOMMENDATIONS

Working Group C (Electro-Optics) held a Special Technology Area Review (STAR) on infrared detector material alternatives to Indium Antimonide (InSb) and Mercury-Cadmium-Telluride (HgCdTe) on 24 March 1994. The conclusions and recommendations from this STAR are as follows:

The very large government and industry investment in HgCdTe development has produced a high-performance, detector-material of choice for most tactical applications. Table 1 summarizes AGEDs consensus opinion on HgCdTe, InSb and PtSi detector material.

Table 1 AGEDs Conclusions on HgCdTe, InSb, and PtSi Detector Materials

Detector	Wavelength				Operating Performance			Relative Production Cost	
	S	M	L	VL	Temp.	Now	Future	Now	Future
InSb		•			77	High	High	Low	Low
HgCdTe	•				190	High	High	Med-High	Low-Med
HgCdTe		•			175	Med-High	High	Low-Med	Low-Med
HgCdTe		•			80	High	High	Low	Low
HgCdTe			•		77	High	High	Med	Med
PtSi		•			77	Med	Med	Low	Low

HgCdTe FPAs are producible and available from multiple sources. Likewise, InSb is a producible detector material that is available for high-performance applications requiring 1μm to 5 μm spectral response. There are alternate detector materials that appear to have the potential to supplement/extend the performance range provided by HgCdTe and InSb. Exploratory funding should be invested in these materials to experimentally quantify their performance potential. System programs should fund the full development of the alternate detector material FPAs when required by the system.

The development of uncooled detectors is going to be driven by commercial investment. DoD should invest in exploring alternate new uncooled detector concepts and in adapting commercial uncooled detectors for military applications. This approach will result in low-cost, producible, uncooled detector arrays with low D* but high sensitivity.

Development of HgZnTe detectors might extend the spectral response. The full cost of developing high quality PV detectors is still unknown even though it is anticipated that most or all of the HgCdTe processes can be used. Full development of HgZnTe only adds marginally to HgCdTe performance (however, overall market impact can be very significant if it replaces HgCdTe as a more stable material).

The GaAs/AlGaAs Quantum Well Infrared Photodetectors (QWIPs), GaInSb/InAs SLSs, and InTlP alloys are III-V detector materials. The use of III-V materials for detectors has at least one major advantage over other detector materials. These materials are also excellent electronic materials. Therefore, the integration of detectors and electronics for smart focal planes is more likely to be possible. Also, use of the same material for detectors and readouts makes fabrication of very large pixel count FPAs possible. In addition, detectors and electronics may be processed on the same production equipment to reduce the cost of FPAs (less capital equipment, less warm-line cost, and lower cost starting materials). In addition, the basic capability to produce detectors can be maintained over time through electronics production even though detectors are not being fabricated.

The optimum application of each III-V detector material is different. The GaAs/AlGaAs QWIPs are likely to be applied in low background situations, such as in space. For example, their high spatial uniformity and low noise, when operated at temperatures less than 40K, can be an advantage in missile interceptors. GaInSb/InAs SLs hold the potential for high performance in the VLWIR (very long wavelength infrared) in NASA-type applications, specifically, and SWIR to VLWIR, in general. The InTlP is the least developed of these III-V materials. However, in the long run, it may hold the potential of replacing HgCdTe with a lower cost material that is more readily developed into smart FPAs. Material growth, surface passivation, and other technical issues plus the cost to develop InTlP make the development of this detector a very high risk.

PtSi is a well developed MWIR detector material that is compatible with Si electronics processing. These FPAs have high spatial uniformity but low quantum efficiency. Extension to LWIR and VLWIR using PtSi/GeSi-Si and spike doped PtSi/Si^{++}Si is under development. Again, development of these detectors should be funded only where systems require their specific performance characteristics.

Table 2 summarizes AGEDs findings on alternate detector materials. The materials are ranked from highest (1) to lowest (8) based on potential to meet projected performance and costs.

No conclusions on the cost or period of time for development of any of these alternate detector materials were reached. The presenters did not address the subject. Cost and development time are very application specific and dependent on the urgency to have a given capability. In addition, no added detector performance requirement was identified that appeared to require special consideration for accelerated development over the present Services' on-going program.

The following are comments and ranking rationale for Table 2:

1. **GaAlAs QWIP production experience is limited. However, being based on mature III-V technology, a learning curve of better than 90% is probable and therefore producibility should be high (i.e., costs should be low).**

2. **HTSCs and Quartz μRes offer potential, but there is currently limited data to support aggressive projections.**

3. **HgCdTe SLs offer limited performance advantages over conventional HgCdTe devices but the required MBE technology is not as mature as III-V layer growth.**

4. **GaInSb/InAs SLs offer high performance and a mature III-V layer growth foundation.**

5. **HgZnTe offers modest performance improvements relative to conventional HgCdTe with a relatively low non recurring investment.**

6. **InTlSb and InTIP offer only modest performance improvements relative to conventional devices and limited potential for learning curves better than 95%.**

7. **Uncooled devices offer good performance based on mature silicon technology. With no need for refrigeration, system costs will be very low.**

8. **SiGe MQWs require excessive cooling.**

9. **Si APD, while based on a mature foundation technology, requires non recurring investment for a limited IR sensitivity (i.e., short wavelength).**

10. **Silicides are based on mature Si technology, however, limited performance (i.e., quantum efficiency and relatively low operating temperature) creates fundamental constraints.**

Table 2 AGEDs Conclusions on Alternative Detector Materials

Alternate Detector	Wavelength				Operating Performance			Relative Production Cost		Ranking
	S	M	L	VL	Temp	Now	Future	Now	Future	
GaAlAs QWIPs			•	•	80/30	Med	High	Low-Med	Low	2
HTSC *			•		?	?	?	?	?	4
HgCdTe SL			•		80	Low	Med	High	Med	5
GaInSb/InAs SL		•	•		80	Low	High	Med-High	Low	1
HgZnTe				•	64	Med	High	Med	Low-Med	3
InTlSb			•		80	?	High	High	Med	7
InTlP		•	•		80	?	High	High	Med	6
Quartz μRes			•		?	?	?	?	?	8
UNCOOLED			•		300	Med	Med	Low-Med	Low	1
SiGe MQW				•	20	Med	High	Med	Med	7
Si APD	•				300	Med	High	Med	Low-Med	5
GeSi/Si, PtSi/GeSi, & PtSi/Si++			•		30-60	Med	Med	Low-Med	Low	4

* high temperature superconductors

REPORT ON THE SPECIAL TECHNOLOGY AREA REVIEW (STAR) ON DETECTOR MATERIAL ALTERNATIVES TO InSb AND HgCdTe

1. Introduction

On March 24, 1994, Working Group C (Electro-Optics) held a STAR on infrared detector material alternatives to InSb and HdCdTe. The principal objectives of this STAR were to determine the development status, limitations and potential of the various material alternatives. This report summarizes the findings of the STAR and makes recommendations for the future development of alternative materials.

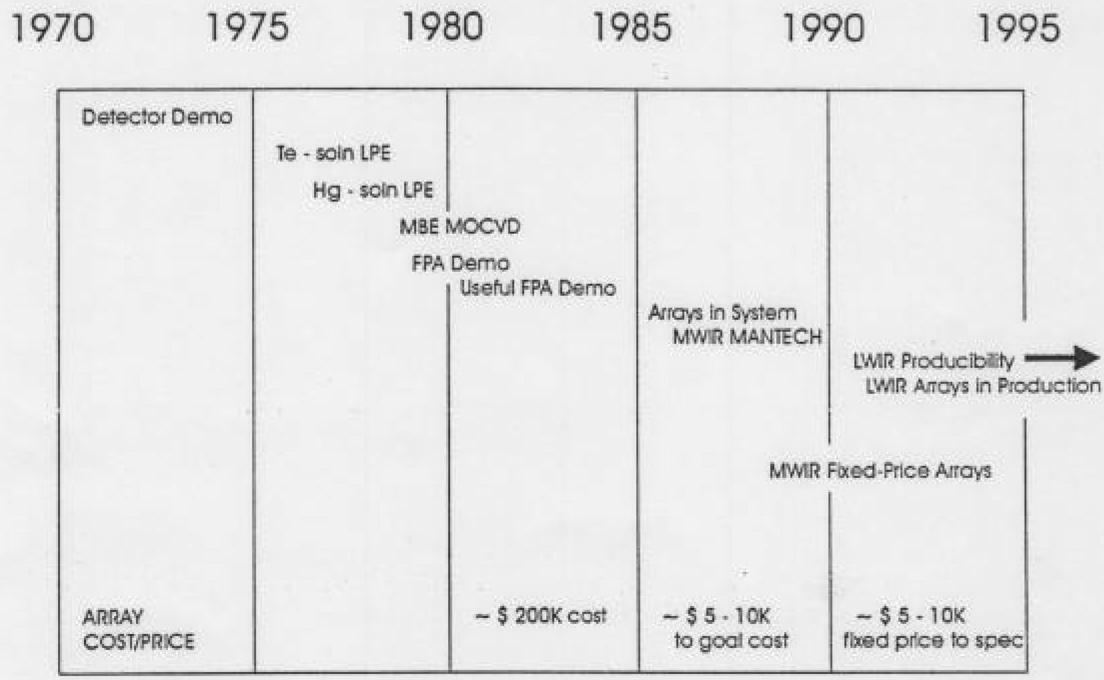
The motivation for holding this STAR was to gather information to make a recommendation for DoD investment strategy in alternative materials. InSb (3-5 mm) and HgCdTe (SWIR to 18 mm) are the premier, high-performance detector materials for DoD systems. In applications where a staring mode is appropriate, PtSi detector arrays are in current use as alternatives to HgCdTe and InSb arrays. The development of InSb, and HgCdTe in particular, have been well funded by DoD resulting in the high performance of the sensor systems which these materials enable. However, there are current and future applications for which InSb and HgCdTe are not optimally suited or are not applicable at all. Declining DoD budgets have forced consideration of the issue of how to divide reduced funding between further development of InSb and HgCdTe, and the alternative materials. The findings and recommendations of the STAR summarized in this report serve as an input to the DoD investment strategy for alternative materials. At present, there does not appear to be any alternative detector material to replace HgCdTe and InSb that has sufficiently high potential as to warrant "full funding". The recommended approach for investing in the further development of any of the alternative detector material candidates that were studied is to provide increments of funding for a series of milestones that will provide information sufficient to assess their technical merits and cost-benefits.

The STAR was conducted by having government and industry technical experts provide presentations (see Appendices A and B) to the Working Group on alternative materials under the Terms of Reference shown in Appendix C. Discussions were held among the presenters, Working Group members, and other government employees subsequent to the presentations to draw conclusions and make recommendations.

2. Background

DoD and industry have invested an estimated one billion dollars (see Figure 1) in HgCdTe detectors and supporting hardware development since discovery of this material in the late 1950's. This investment has paid-off by allowing the realization of a high performance detector which is flexible in configuration and has a cut-off wavelength that makes it suitable for use in many DoD applications. However, limitations of the material for many DoD applications remain. Table 3 provides a list of factors to be considered in selecting an IR detector material. Based on this table, some of the limitations of HgCdTe which may justify the development of an alternate detector material are shown in Table 4. InSb, like HgCdTe, is a high performance detector, but limited to cutoff wavelengths of less than 5.6 mm. Table 5 summarizes some of the InSb limitations that may justify development of an alternate detector material.

Figure 1 Approximate 2nd Generation HgCdTe Technology History Shows Cost of Major IR Technology Development



Cost was more than $ 1B counting Industry & Government Investments

Table 3 Factors to be Considered in Selecting an IR Detector Material

PERFORMANCE	• Sensitivity in a defined spectral band with a specified array configuration, optical train, and electro-mechanical configuration for a given operating environment
SUPPORT FUNCTIONS	• Electrical readout • Cooling • Optical train • Radiation hardening • Stealth • Mechanical (i.e., scanners and vibration isolation)
CONFIGURATION	• Number of pixels • Fill factor • Pixel geometry (individual and position relative to other pixels) • Single or multiple planes of focus
APPLICABILITY	• Suitable/adaptable to multiple types of missions • Suitable/adaptable to multiple types of systems
COST	• To complete development • System integration • Packaging • Production facilitation for given volume • Production for a given volume • Logistics cost (operating, maintenance, storage, transport) • Replacement cost
AVAILABILITY	• Time to be able to produce • Production time • Reliability • Storage life

Table 4 HgCdTe Detector Materials

ISSUE	LIMITATIONS OF HgCdTe DETECTOR MATERIAL	MEASUREMENT PARAMETERS
COST/AVAILABILITY	• HgCdTe Production line can only be used for HgCdTe - therefore expensive • HgCdTe expensive detector material to process • Packaging (dewar and cooler) is very expensive relative to the FPA	• Detector material can be processed on electronic circuit processing line • Cost of FPA in volume • Cost of packaging
FUNCTIONALITY	• Poor or no performance for wavelengths greater than 18 μm • Poor or no performance uncooled • Demonstrated 8 year shelf life	• D* for wavelengths greater than 18μm • D* in 8-12μm spectral band at room temperature • 10 year shelf life
PERFORMANCE	• Poor spatial uniformity without sophisticated calibration • NEDT high for low background applications	• Variance of NEDT for FPA • NEDT at temperatures less than 40°K operating temperature
ENHANCED PERFORMANCE POTENTIAL	• Thermal expansion mismatch in HgCdTe & Si readout limit size of array • HgCdTe is not as good an electronic material as Si; requires hybridization or epitaxial growth on Si • Limited pixel-matched, multi-color performance	• Thermal cycle testing • Defects in HgCdTe and electrical properties • Noise and sensitivity in multiple wavelength bands

Table 5 InSb Detector Materials

ISSUE	LIMITATIONS OF InSb DETECTOR MATERIAL	MEASUREMENT PARAMETERS
COST/AVAILABILITY	• Packaging (dewar and cooler) is very expensive relative to the FPA	• Cost of packaging
FUNCTIONALITY	• Poor or no performance for wavelengths greater than 5.5μm • Generally limited to operating temperatures less than 100°K	• D* for wavelengths greater than 5.5μm • D* at temperatures greater than 80°K
PERFORMANCE	• Spatial non-uniformity limits performance at high background levels without sophisticated calibration • Spatial non-uniformity limits performance at low background without offset calibration	• Variance of NEDT for FPA • Variance of NEDT for FPA
ENHANCED PERFORMANCE POTENTIAL	• Thermal expansion mismatch in InSb and Si • Pixel-matched, multi-color performance improbable	• Thermal cycle testing • Noise and sensitivity in multiple wavelength bands

Based on the perspectives provided by the Rockwell International Science Center, Lockheed Research and Development Division, AF Wright Laboratory, AF Rome Laboratory and CECOM NVESD, some general statements on the current state-of-the-art and future requirements in IR detector materials are possible. These are:

1. SWIR and MWIR HgCdTe FPAs approach radiative limits at temperatures to 200°K.
2. Lattice matched InGaAs FPAs at 1.7 μm approach radiative limit at room temperature.
3. Lattice matched InSb FPAs approach radiative limit at 77°K.
4. LWIR HgCdTe approach Auger limit at 77°K.
5. MWIR HgCdTe 256x256 Hybrid FPAs have survived 3000 thermal cycles with less than 0.3% pixel loss.
6. Greater than 99% operable MWIR HgCdTe FPAs with areas greater than 3 cm^3 have been imaged.
7. Hybrid FPA pixel size has dropped to less than 20 μm for HgCdTe and InSb.
8. 640x480 HgCdTe FPAs have been demonstrated and 1000x1000 FPAs are anticipated to be demonstrated in the near term.
9. FPA performance can be limited by the system implementation and application, as well as the performance of the detectors.
10. There are space applications for FPAs with sensitivity beyond 18 μm with operating temperatures greater than ~30°K for which acceptable FPAs do not exist.
11. Future FPAs must have enhanced performance, such as being smart and being able to detect multiple spectral bands of radiation.
12. Packaging, including the dewar and cooler, is the dominant system and life cycle cost component for an FPA assembly.
13. IRFPA II has reliability demonstrated to 3000 cycles with no change in operability, using silicon and CdZnTe substrates.
14. There is production of 640x480 PtSi arrays at three U.S. manufacturers. Two have delivered "zero defect" arrays. The third, Mitsubishi, has developed a 1040x1040 array.
15. As delivered, PtSi arrays have rms response uniformity between 0.3% and 2%, and low 1/f noise, allowing very long term compensation in the 0.025% range.

These statements indicate that HgCdTe and InSb are generally detectors of choice. There are niche applications where extended performance of HgCdTe, InSb, or an alternative detector materials are required for high performance applications. There are current thermal imaging applications where high performance has been demonstrated with PtSi based IR cameras. Certain applications can be accomplished with lower performing detectors. For these applications, uncooled IR detectors may have adequate performance. This will result in lower cost, realized by reducing packaging cost.

3. Discussion of Alternative Detector Materials

Appendix B groups the STAR presentations by class and type of detector material. A summary of the presentations and WGC discussions by type of detector material is presented in the following paragraphs and in Table 7.

3.1 QWIP

The development of GaAlAs/GaAs QWIP FPAs has progressed very quickly. Initial work, started in the early 1980's, was based upon previous work on electronic devices. Currently 256x256 arrays can be reproducibly fabricated with high yield, high spatial uniformity (0.02% without gratings after compensation), essentially no 1/f noise at frequencies as low as 10 Hz, and relatively low cost. In addition, initial demonstrations of 2-color FPAs have been accomplished with an overlay of two separate FPAs. The QWIPs fabricated from III-V materials should be radiation and laser hard.

Several aspects of QWIP technology require further development. Device designs, including grating structures, need to be developed that do not degrade the spatial uniformity of spectral response of the FPA, yet increase the quantum efficiency of the devices. Dark currents are high, especially at 80°K, resulting in the degradation of the D* of these FPAs. Development work on materials and device structures to lower dark currents is required. Also, additional development of materials, device structures, and drive electronics is needed to optimize performance for VLWIR FPAs.

Currently , GaAlAs/GaAs QWIP FPAs appear to offer the most potential for low background detection when operated at approximately 40°K

3.2 HgZnTe

In some respects, HgZnTe is a comparable detector material to HgCdTe, but it has potentially superior handing characteristics and detector performance, especially for VLWIR detection. The reason that HgZnTe has handling characteristics theoretically superior to those of HgCdTe is that it is mechanically harder, resulting in reduced damage during polishing and other processing. Improved VLWIR detector performance may result because the material has fewer dislocations, fewer native point defects, and suppressed concentration fluctuations. Also, the material may have increased concentration stability compared to HgCdTe that results from reduced tunneling currents with larger effective election mass.

HgZnTe detector processing is compatible with that of HgCdTe detectors. This results in low process development costs. HgZnTe liquid phase epitaxial (LPE) photoconductive (PC) arrays have been fabricated using the same processes as for HgCdTe with 15 μm to 19 μm cut-off wavelengths and background limited performance (BLIP) at 64°K. These detectors show no change in D* after a 26 day bake at 100°C; they are therefore only as good as HgCdTe ones. Development of photovoltaic (PV) HgZnTe detectors remains to be accomplished.

3.3 GaInSb/InAs Strain Layer Superlattice (SLS) FPAs

GaInSb/InAs SLS FPAs are intrinsic superlattice detectors with projected performance analogous to that of HgCdTe. However, the technology is very immature. The potential benefits of this class of detector materials, relative to HgCdTe, are higher operating temperature (reduced Auger and tunneling currents), improved spatial uniformity, longer cut-off wavelengths (3 to 20+ μm), capable of production using developed III-V processing methods, compatibility with III-V electronics for on-chip signal processing, and having the potential for pixel-matched, multi-color operation. In addition, this material structure may operate as an IR emitter at a higher temperature than lead salt diodes.

Photoconductive devices have been demonstrated with cut-off wavelengths from 3.5 to 14 μm, specifically D^*_{BB} (500K) BLIP = 10^{10} Jones at 80°K and 10 μm cut-off. N-N-P double heterojunction diodes (n-InAs/n^--GaInSb/InAsSL/p^+-GaSb) in small arrays (25) have been demonstrated to have R_oA of 160 ohm-cm^2 with low dark current. These early results demonstrate the performance potential of these detectors and also serve to identify a number of areas where significant further development is required. Doping of the material is an issue. Undoped n-type material has concentrations of 10^{15} - $10^{16}/cm^3$, so the control of background doping is an issue. Carrier lifetimes are currently in the nanosecond range but need to be many orders of magnitude larger for high performance detectors. The cause of these short lifetimes is not known and may be due to surface, bulk or interface mechanisms. Surface passivation and electrical transport perpendicular to the layers of the superlattice structure are also significant issues that must be resolved.

3.4 InTlSb and InTlP

Theoretical calculations have been carried out to assess the potential detector performance of InTlSb and InTlP. The calculations indicate that these materials should have high, spectrally-flat quantum efficiency, low noise, high absorption coefficients, and high mobility comparable to that of HgCdTe. However, this class of materials should have superior thermomechanical properties to HgCdTe and therefore fewer imperfections, enabling higher performance detectors than HgCdTe ones. Also, these materials are compatible with III-V material substrates for on-chip electronic processing. None of these calculations have been verified because the materials have not yet been grown or processed into detectors for testing.

3.5 PtSi/GeSi-Si and PtSi/SI++Si

PtSi detectors have demonstrated advantages of full compatibility with silicon integrated circuits, high producibility, minimal 1/f noise, high spatial uniformity and 1 μm to 5 μm spectral responsivity in a single array. Current array sizes range from $(256)^2$ to $(1040)^2$ and pixel sizes range from 17μm to 40μm. PtSi arrays have low quantum efficiency, determined by conservation of emitted carrier momentum, and requirement for operation at, or below 77°K. Despite low quantum efficiency, PtSi camers having NEDTs below 0.06°C and low frequency MRTs below 0.007°C have been demonstrated.

Current research in PtSi and related heterojunction devices is directed at:

- Increasing detector cut-off wavelength
  - To extend PtSi response into the LWIR
  - To increase quantum efficiency at all wavelengths below cut-off
- Increasing emission efficiency
- Increasing operating temperature

Through the use of GeSi alloys at the substrate surface, spectral response has been extended to 10μm. The use of degenerate silicon surface layers has given controlled cut-off wavelength, ranging from 14μm to 20μm. GeSi/Si heterojunctions have similar cut-off wavelengths and the potential for increased quantum efficiency, related to the low Fermi energy of the degenerate GeSi Schottky electrode. All of these Schottky detectors have been demonstrate either as single detectors, or as arrays. They are manufactured using extensions of silicon integrated circuit fabrication processes. Thus, this development area offers a low risk approach to realizing large, producible detector arrays for the LWIR spectrum.

3.6 Uncooled Detectors

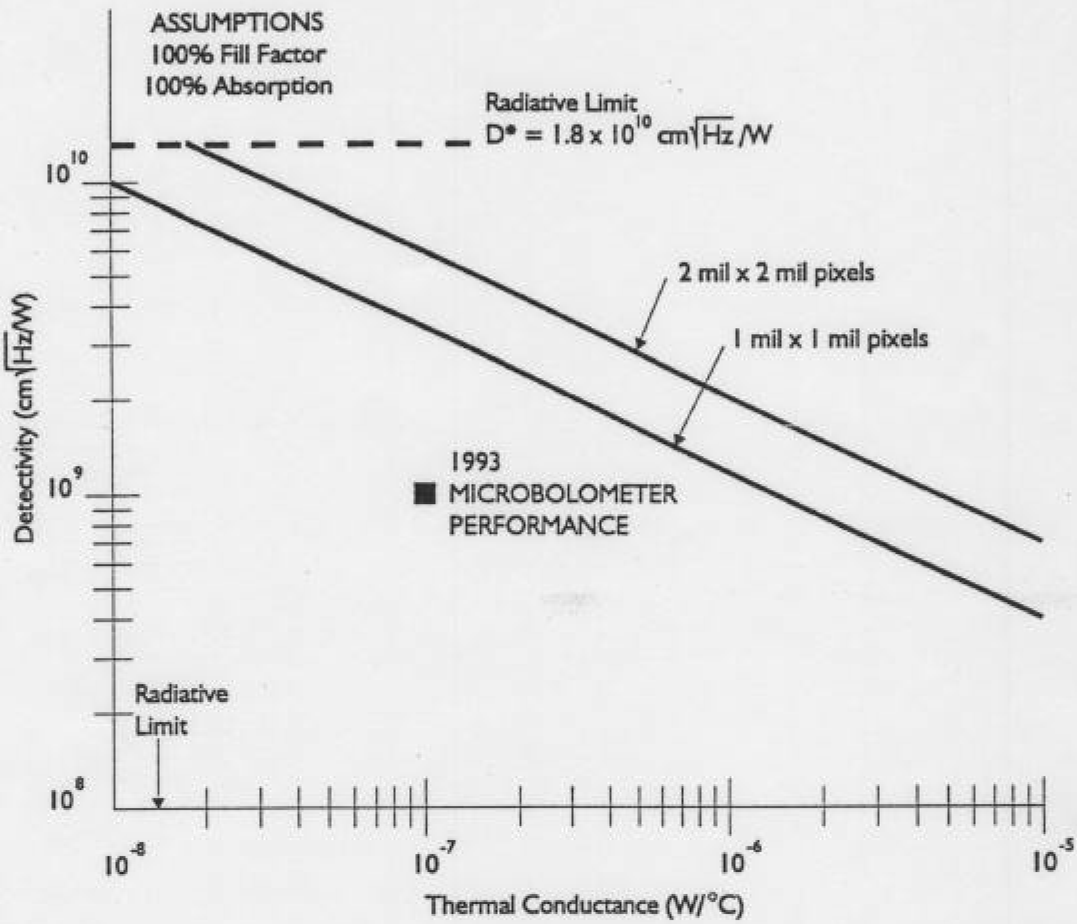
Silicon microbolometers have been developed sufficiently to appear viable for a number of commercial and military applications. Typical performance of high quality devices, as provided by Honeywell, is shown in Table 6.

Table 6 Typical Microbolometer Parameters

Mass (silicon nitride)	10^{-9} g
Thermal mass	10^{-9} J/C
Thermal conductance to substrate	10^{-7} W/C
Thermal response time	20 ms
Operating temperature	Room temperature
Vacuum	<100 mTorr
Fill factor	50%
Shock tolerance	>20,000 g as a goal
Absorption (8 to 18 μm band)	80%
Pixel size	2x2 mils
Bias voltage	5 V
Resistance	20 kΩ
k value	10^{-14}
TCR (vanadium oxide)	-2%/C
Responsivity	250,000 V/W
Noise	15 μV rms
Sensitivity (NETD)	0.04 C (F1.0, 30 Hz frame rate, 50 μm pixel)
Array dimensions	240x340 pixels
Readout	monolithic bipolar
Waveband	8-14 μm
Dynamic Range	~32,000
Pixel time constant	20 msec.
MTF	ideal
D*	~8×10^{8} cm $Hz^{1/2}$ W^{-1}

Further development of readout electronics and detector fabrication is projected to yield 1 mil pixel size detectors with NETD improvement to 0.01°C. However, these detectors have limited D* performance as shown in the following chart presented by Loral.

Figure 2 Calculated D* for Microbolometers



Texas Instruments has been developing ferroelectric uncooled detector FPAs using barium strontium titanate material. 245x328 pixel arrays have been fabricated with 48 μm pixel size. Special 1 μm CMOS readout electronics which are bump bonded to the detector array have been designed and fabricated to provide gains of 200 and a 10 to 120 Hz passband noise filter, using a 30 Hz diffusive chopper. A monolithic ferroelectric technology is currently under development which could provide NETD of less than 0.01°K and a 3X improvement of MTF.

Other types of uncooled FPAs are under early development. These include thermo-electric, high temperature superconducting, quartz microresonator and ones fabricated from new bolometric and pyroelectric materials. Investment in development of these advanced concepts is significantly less than in the Honeywell Si-microbolometer and the TI-ferroelectric uncooled FPA concepts.

Table 7 Alternative Materials

MATERIAL	DEVELOPMENT STATUS	PRIMARY APPLICATION
HgZnTe	• PC arrays with 19 μm cutoff and BLIP Performance • 26 Day, 100°C bakeout with no degradation	• Replacement for HgCdTe • Longer cutoff wavelengths (~20 μm) than HgCdTe
PtSi/SiGe & PtSi/Si	• PtSi/SiGe arrays with cutoff wavelengths of 10 μm demonstrated • $PtSi/Si^{++}$ material studies show high emissivity to 20 μm	• Very large, rugged, staring sensor arrays for LWIR • Where cooling below 77K is acceptable
QWIP	• 256x256 arrays • Uniformity 0.02%, with grating 2% • 2 color (MWIR & LWIR) • Peak responsivity 4.7 μm to 17 μm • D* @ 17 μm $5x10^{13}$ at 30 K $2x10^{12}$ at 40 K $2x10^{10}$ at 77 K ~40% • BLIP IFBB • High dark current at temperature › 40°C • QE < 20%	• Low background detection with detector operating at less than 40K, multicolor
SLS	• Theoretical work only • Material issues • PC devices with D^*_{BB} (500K) = 10^{10} Jones at 80K and 10 μm cutoff wavelength demonstrated	• Replacement for HgCdTe • Longer cutoff wavelengths and higher operating temperatures than HgCdTe
III - V ALLOYS (InTlSb/InTlP)	• Theoretical work only	• Smart FPAs demonstrated by InSb and HgCdTe • Possibly a few percent more mechanically robust than HgCdTe
II-V SLS (GaInSb/InAs)	• Early development • Materials issue • PC devices with D^*_{BB} (500K) = 10^{10} Jones (~20% Blip) at 80K and 10 μm cutoff wavelength demonstrated	• Replacement for HgCdTe • Longer cutoff wavelengths and higher operating temperatures than HgCdTe
UNCOOLED	• Si microbolometer with 2x2 mil pixels in 240x340 arrays with NETD of 0.04K and D* of $8x10^8$ • Ferroelectric FPAs with 48 μm pixels and 245x328 elements and NETD of 0.075K	• Short-range, low-cost IR imaging systems • Potential for high sensitivity or long range, low cost IR imaging systems

Appendix A STAR Presenters and Subjects Presented

PRESENTER	ORGANIZATION	SUBJECT
Anjali Singh	USAF PL	QWIP: AN INTRODUCTION
J.R. Waterman	NRL	GaInSb/InAs Superlattice Materials
Wayne Chang	ARL	Performance Assessment of QWIPs
R.A. Wood	Honeywell	Uncooled Silicon IR Microbolometer Arrays
John Pollard	CECOM NVESD	Uncooled Detectors and Other Topics
Chip Marshall	LIRIS	Uncooled Infrared at Loral
Arden Sher	SRI	Alternative Alloys for FPAs
M. Miller	ARL - EPSD	Quartz Microresonators
Thomas Lewis	Advanced Photonix	APDs for Low Light Level, High Speed Imaging
T.S. Faska	Martin Marietta	Performance of 256x256 LWIR Miniband Transport Multiple Quantum Well FPA
R.L. Whitney	Lockheed	Systems Applications of New Infrared Detector Technologies
R.H. Miles	Hughes Research Lab	Infrared Detectors Based on GaInSb/InAs Superlattices
William Radford	Hughes Santa Barbara Research Center	Alternative Detector Materials to InSb and HgCdTe
W.E. Tennant	Rockwell	Considerations in Choosing IRFPA Technology Alternatives to MCT and InSb
Freeman Shepherd	AF Rome Lab	Platinum Selicide and Related Internal Photoemission Detectors.
W.C. Mitchel	AF Materials Lab	Alternative Detector Materials
John Bruno	ARL	InAsSb/InSb
Charles Hanson	TI	Monolithic UFPA

Appendix B Presentations by Technical Area

CLASS	TYPE	REPORTING ORGANIZATION
III-V	QWIP (GaAlAs/GaAs)	AF/PL ARL MM
III-V	SLS (GaInSb/InAs)	NRL Hughes SBRC
III-V	Lattice Matched InTlSb InTlP InGaAs InAsSb	 — SRI — SRI — Rockwell — Rockwell
Uncooled	Si Microbolometer Bolometer Pyroelectric Quartz Microresonator	— Honeywell — NVL — LORAL — Hughes SBRC — TI — ARL
Silicides	PtSi/GeSi	— AF/RL
II-VI	CdZnTe	— NVL — SRI — Hughes SBRC
SURVEY	N/A	Rockwell - Science Center Lockheed - Research & Development Div. AF Wright Laboratory CECOM NVESD

Appendix C STAR Terms of Reference

Objectives:

1. Collect material parameters, performance characteristics, and geometrical configuration data and analytical results on detector materials, detectors and focal plane arrays for:

   thermal detectors
   multi quantum well detectors
   new detectors, for example InTlSb

2. for detection in the 1 to 25 μm spectral region.

3. Quantitatively compare the performance of alternative detectors to HgCdTe and InSb detectors in 2D focal plane array configurations, identifying advantages and limitations.

4. Identify niche applications (with volume required) for the alternative detector material focal plane arrays.

5. Identify development areas for the alternative detector material focal plane arrays along with associated investment level and period of development time

6. Project availability (time, quantity, cost) of alternative detector material focal plane arrays

Presenter:

1. Provide information on each alternative detector material presented for items (1) to (5) in above objective.

2. Provide recommendation on methods and means to fund further development of alternative detectors.

3. Provide volume and time frame projections for use by the government and commercial companies of alternative detector material focal plane arrays.

Report:

1. Presentation to government personnel, AGED members, and all presenters (if all presenters agree), otherwise presentation is only to government personnel and AGED members.

2. Hard copy of presentations provided to AGED members and government employees.

3. Page summary report for release to public upon approval by the government and presenters.

4. Potential IRIS conference presentation on results of STAR.